Preliminary Analysis of fourth Cavity Production (Zanon Cavities)

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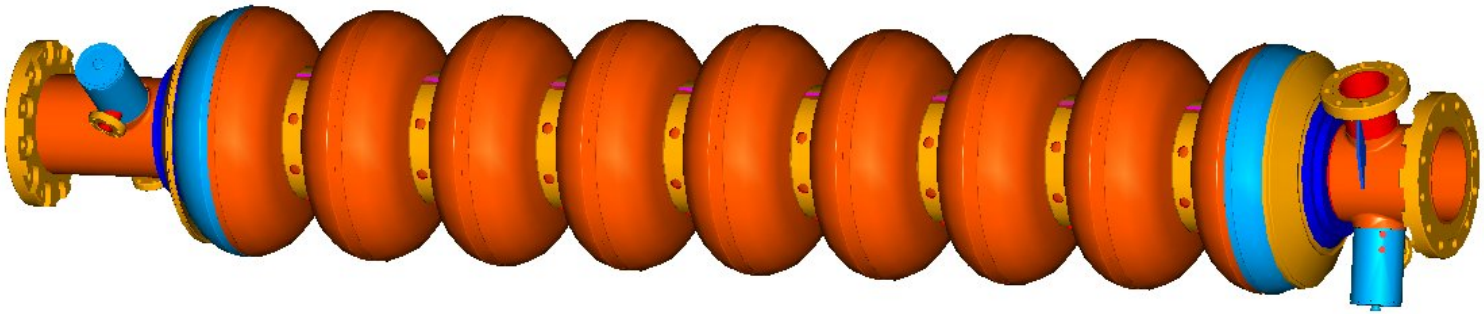
- Indroduction
- Data analysis
- Results + Quench locations
- Vertical vs. Chechia test results
- Summary + conclusion

Introduction

- Fourth cavity production series:
  - 30 nine-cells fabricated by Zanon company
    (incl. 3 prototypes with irregularities during fabrication)
  - 15 cavities of Teledyne Wah Chang Nb; 14 cavities of Tokio Denkai Nb;
    1 mixed cavity
  - delivery from mid 2004 to end of 2005
- "Standard" cavity preparation:
  - first EP of 150µm, outside etching, 800C firing, final EP of (40 - 50) µm, test, 120C bake, test

  => but many changes + exceptions !!!



Introduction II

- Cavity Processing:
  - Z82 – Z84 (prototype cavities) got 1350C titanisation
  - 8 cavities are/will be etched (10 µm) as final treatment
  - 120C bake is skipped due to lack of time (=> module completion)
- Cavity Testing:
  - 21 cavities vertically tested
  - 7 cavities Chechia tested; 2 under preparation
- Remark:
  - Z84 not included due to multiple Q-disease !!
  - Z82 + Z83 after 1350C not included

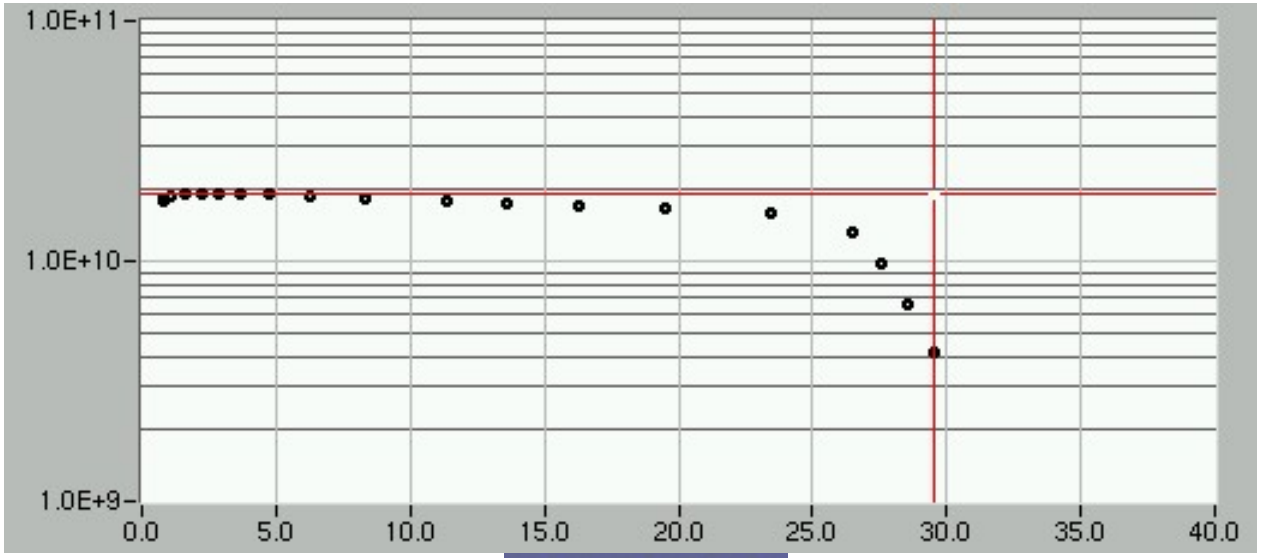
Data analysis

- Comparison of maximum and usable gradient after various preparations
  => bad statistics due to many different ways of preparation
- Usable gradient in vertical test:
  Lowest value of gradient for either
  - quench
  - x-rays exceed 10^{-2} mGy/min
  - or rf losses exceed 100 W in cw operation (comparable to app. 1 W pulsed)
    => limitation of cryogenics !!
- Analysis of
  - final EP- vs. BCP-treatment
  - comparison before and after 120C bake

- Not strictly following “first/last/best test” like in data base
  => Choice of “reasonable” test (see add. transparencies)
  (e.g. 14 of 20 cavities first test used before bake)

Expectation: 800C,**EP**, before bake

- Preparation: final EP after 800C firing + 150µm EP before 120C bake
- Expectation for a “good” (typical) cavity:
  - $E_{acc,max}$ between 25 MV/m and >30 MV/m, Q-slope without field emission, limited by available power, no up to moderate field emission
  - Usable gradient between 25 MV/m and 30 MV/m limited by rf/cryo losses
- Typically cavities not used for accelerator without bake, but …
- Example of Z87:



Results: 800C,**EP**, before bake

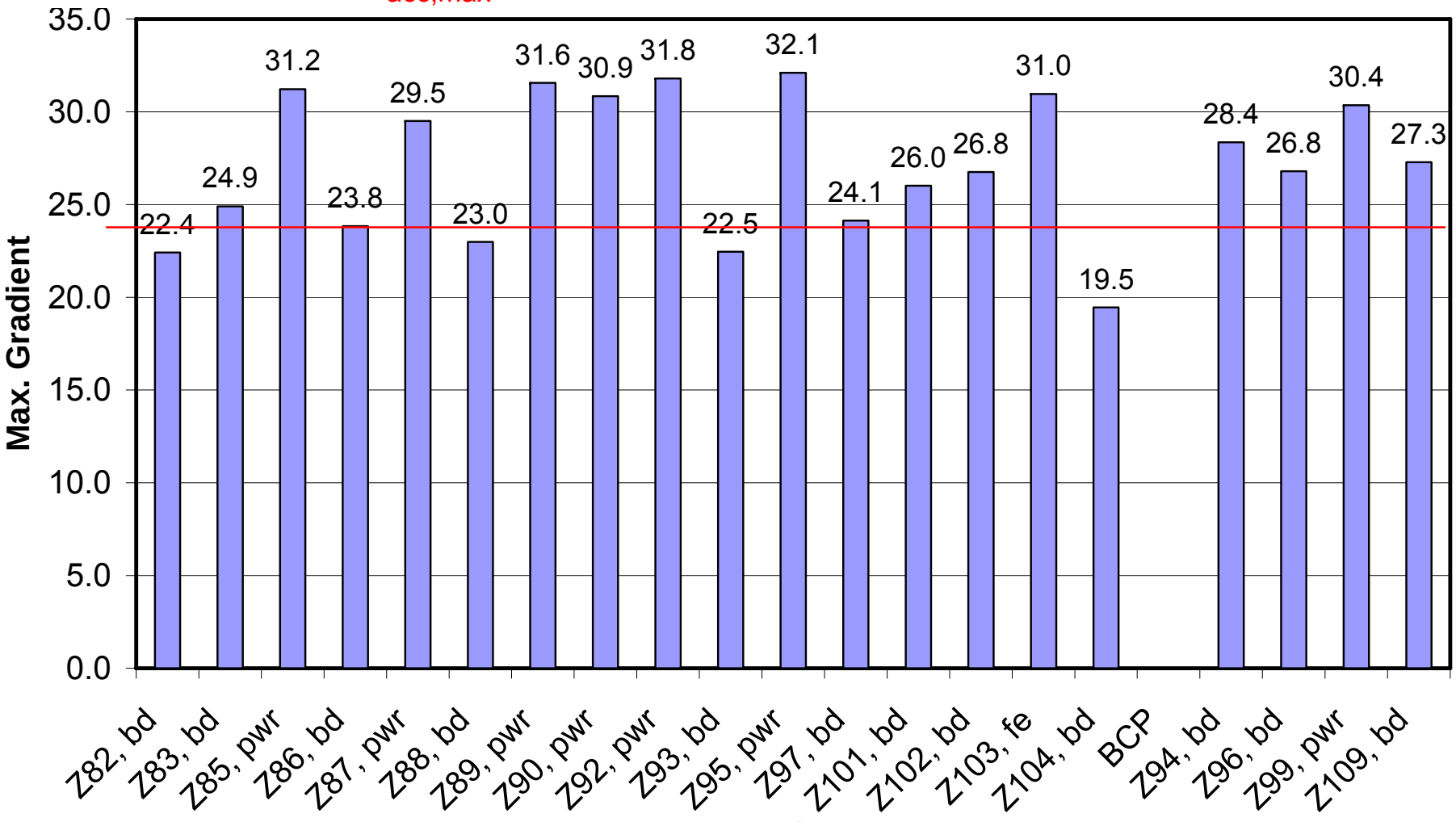
- Analysis of 16 cavities after final EP, before 120C bake :
- Maximum gradient $E_{acc,max}$
  - 9 cavities limited by quench (bd)
  - 6 cavities limited by power
  - 1 cavity by FE (extremely high x-ray level=

  - 7 of 9 cavities limited by quench below 25 MV/m !!
- Some quenches maybe field emission induced e.g. Z82, test1 !!!

- Usable gradient:
  - for 8 cavities field emission dominates !!
  - 4 cavities are quench limited => $E_{acc,max} \approx$ usable gradient
  - 4 cavities exceed tolerable cryo losses (partially close to quench)

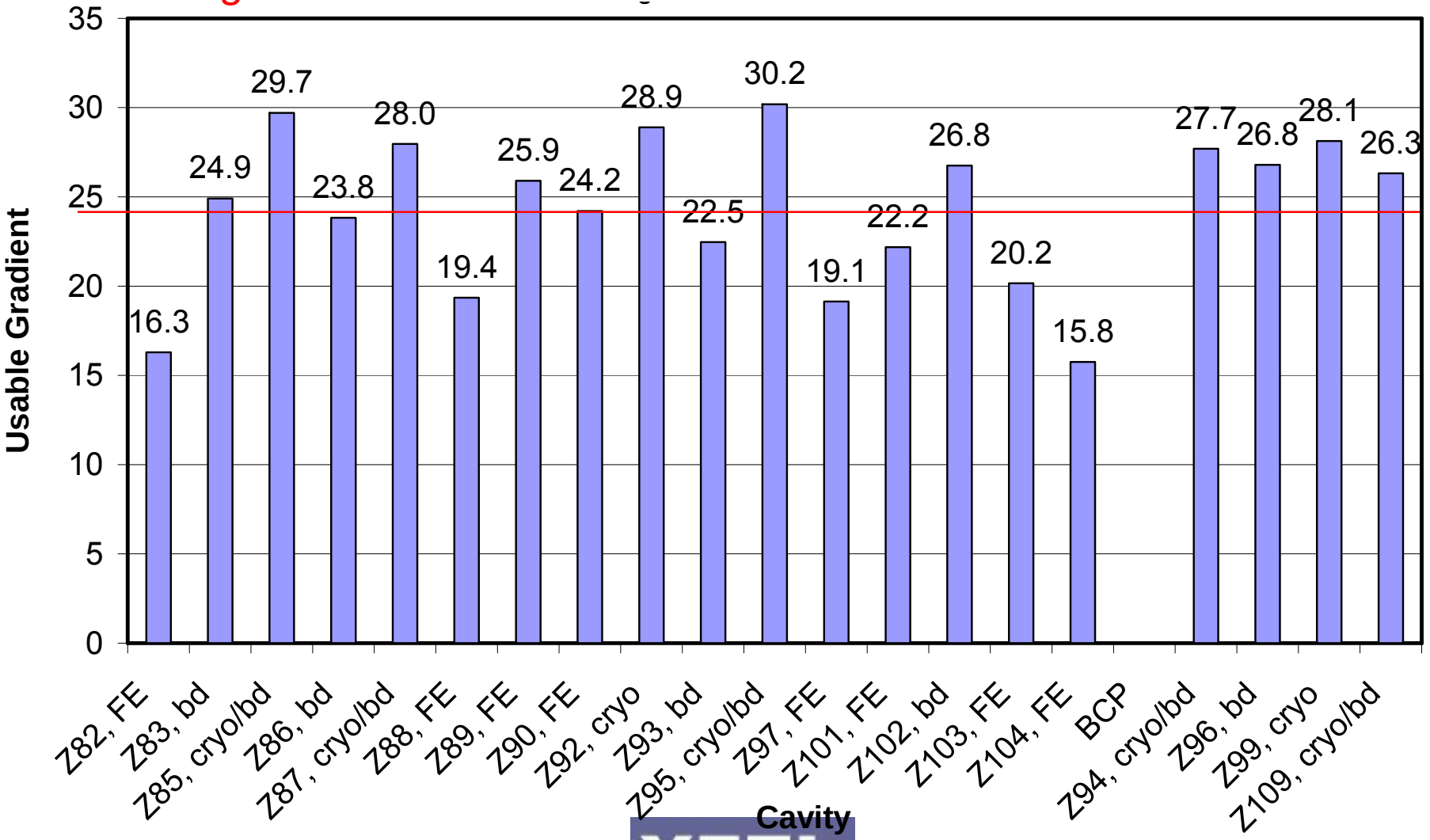
$E_{acc,max}$ before 120C bake

- Comparison of $E_{acc,max}$ after final EP and BCP-treatment before 120C bake:



Usable gradient before 120C bake

- Usable gradient after final EP and BCP-treatment before 120C bake:



Results: 800C,**BCP**, before bake

- Preparation: final BCP of 10µm after 800C + 150µm EP before 120C bake
- Expectation for a "good" (typical) cavity:
  - only few data available, but probably similar to "pure" EP
  ($E_{acc,max}$ between 25 MV/m and >30 MV/m, Q-slope without field emission, limited by available power, no up to moderate field emission)
  - Usable gradient also similar (between 25 MV/m - 30 MV/m limited by rf/cryo losses)
- Intended to treat and test 8 cavities => 4 cavities done

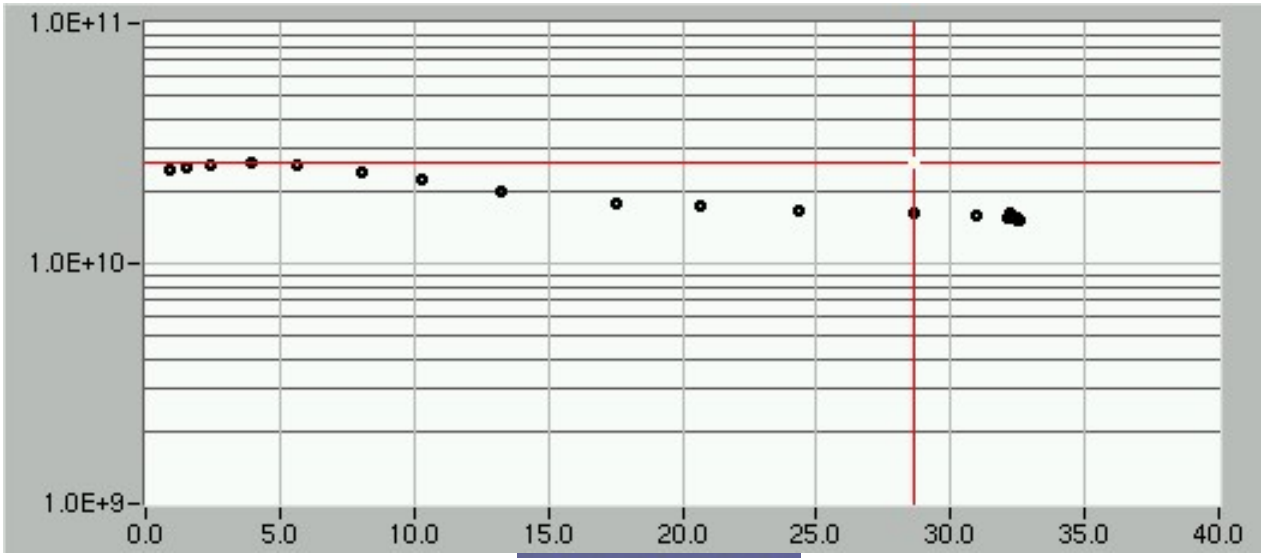
- Maximum gradient $E_{acc,max}$
  - 3 cavities limited by quench (bd)
  - 1 cavity limited by power
- Usable gradient:
  - 1 cavity quench limited => $E_{acc,max} \approx$ usable gradient
  - 3 cavities exceed tolerable cryo losses (partially close to quench)

Expectation: 800C,**EP**, after bake

- Preparation: final EP after 800C firing + 150µm EP after 120C bake
- To achieve full Q(E)-performance of EP-cavities 120C-bake is required!!
- Expectation for a “good” (typical) cavity:

  - $E_{acc,max}$ >30 MV/m, no or nearly no Q-slope, limited by quench (bd), no up to moderate field emission

  - Usable gradient >30 MV/m (?) limited by rf/cryo losses
- Example of Z87:



Results: 800C,**EP**, after bake

- Analysis of 7 cavities after final EP, after 120C bake :
- Maximum gradient $E_{acc,max}$
  - 6 cavities limited by quench (bd) between 24,5 MV/m and 33 MV/m
  - 1 cavities limited by rf-problems
  => 3 cavities limited by quench just below 25 MV/m !!
- No cavity exceeds x-rays of 10^{-2} mGy/min !!

=> Often no improvement after 120C bake due to quench limitation!!

Usable gradient:

- 6 cavities are quench limited => $E_{acc,max} \approx$ usable gradient
- 1 cavity rf limited => $E_{acc,max} \approx$ usable gradient

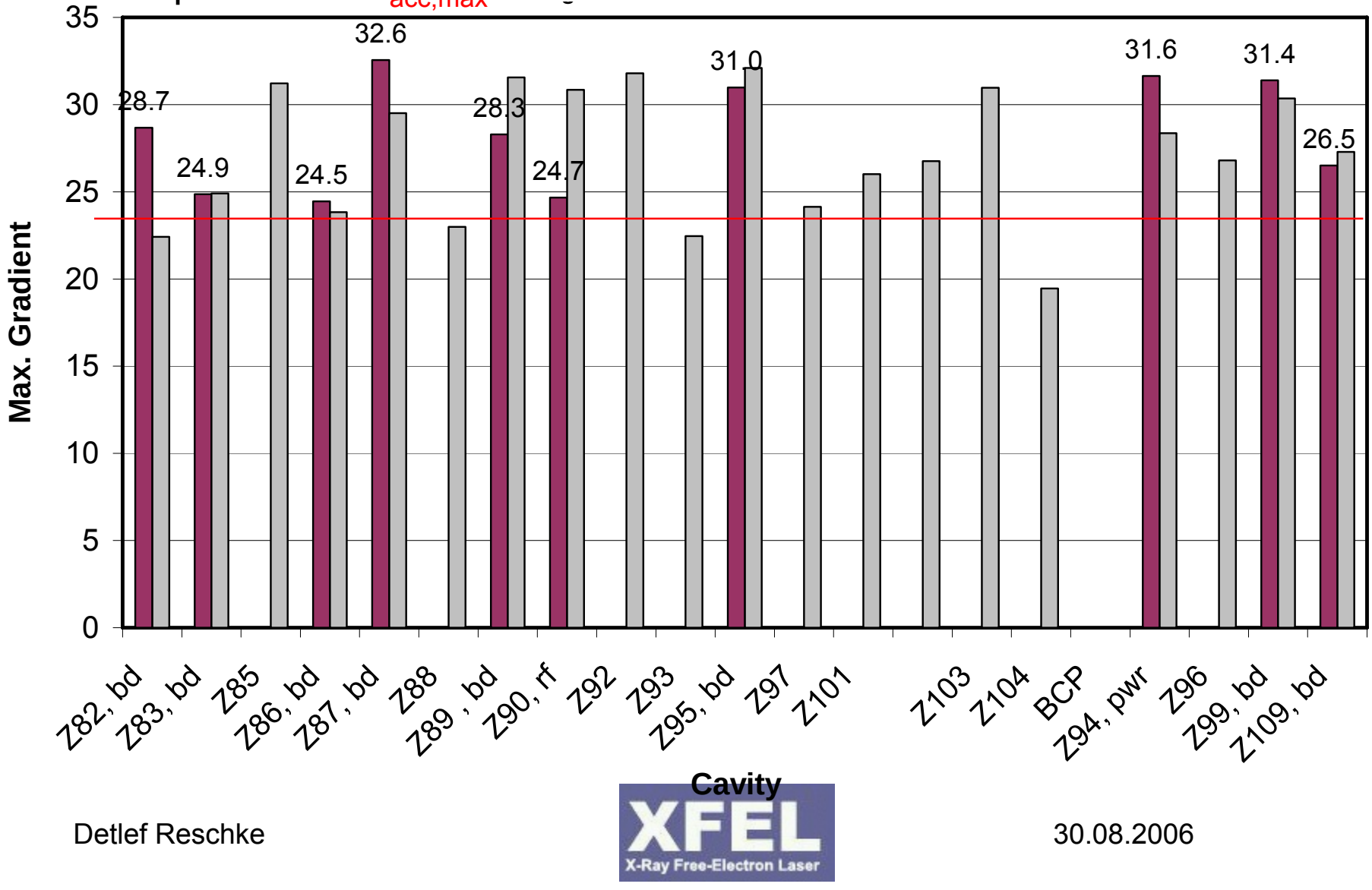
Results: 800C, **BCP**, after bake

- Preparation: final BCP of 10µm after 800C + 150µm EP after 120C bake
- Expectation for a “good” (typical) cavity:
  - only few data available, but probably similar to “pure” EP
  ($E_{acc,max}$ >30 MV/m, (nearly) no Q-slope, limited by quench, no up to moderate field emission)
  - Usable gradient also similar (> 30 MV/m (?) limited by rf/cryo losses)
- Intended to treat and test 8 cavities => only one cavity tested after bake !!

- Maximum gradient $E_{acc,max}$
  - 1 cavity limited by quench
- Usable gradient:
  - 1 cavitiy exceeds tolerable cryo losses (2 MV/m below quench)

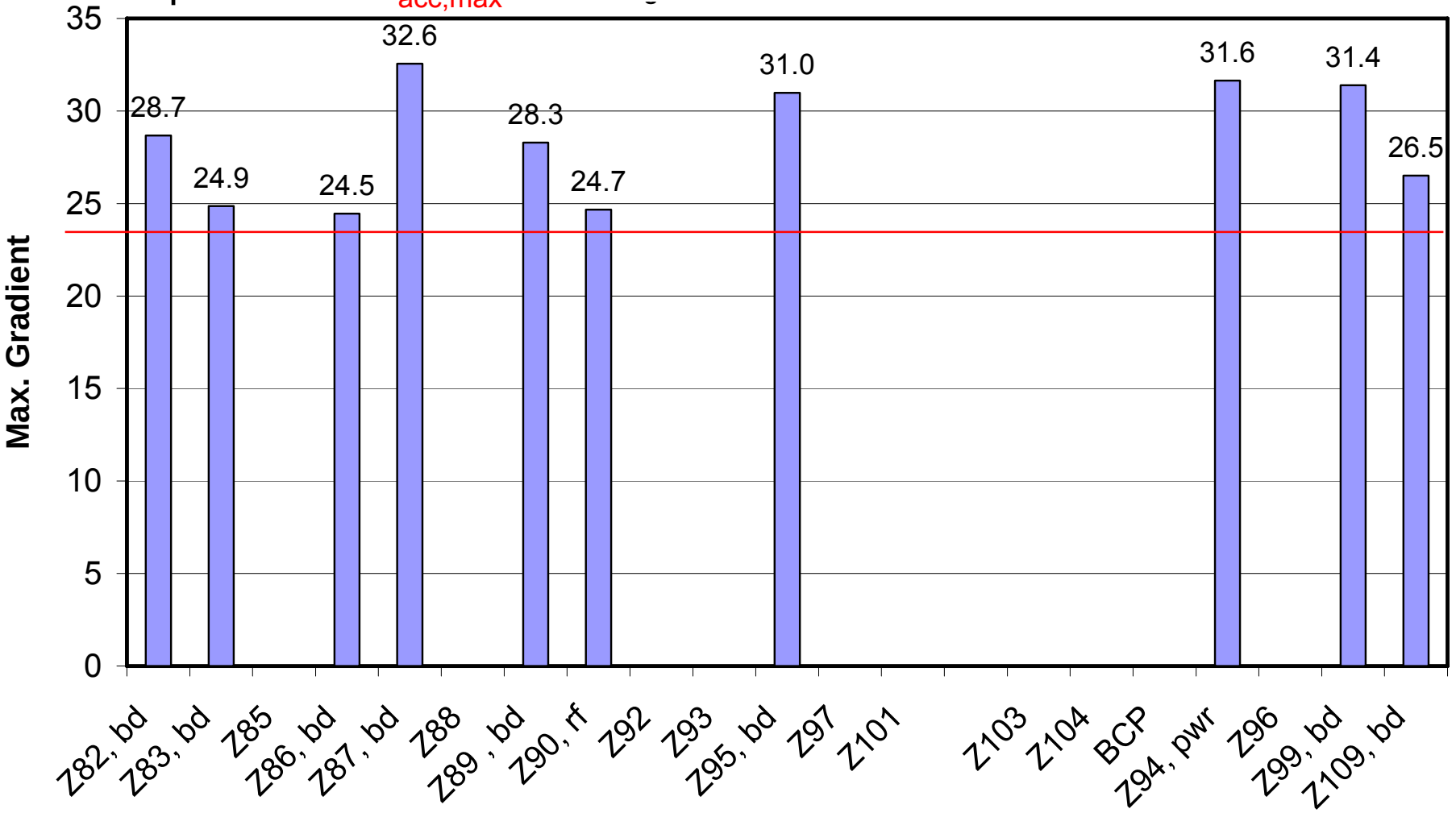
$E_{acc,max}$ before and after 120C bake

- Comparison of $E_{acc,max}$ before and after 120C bake:



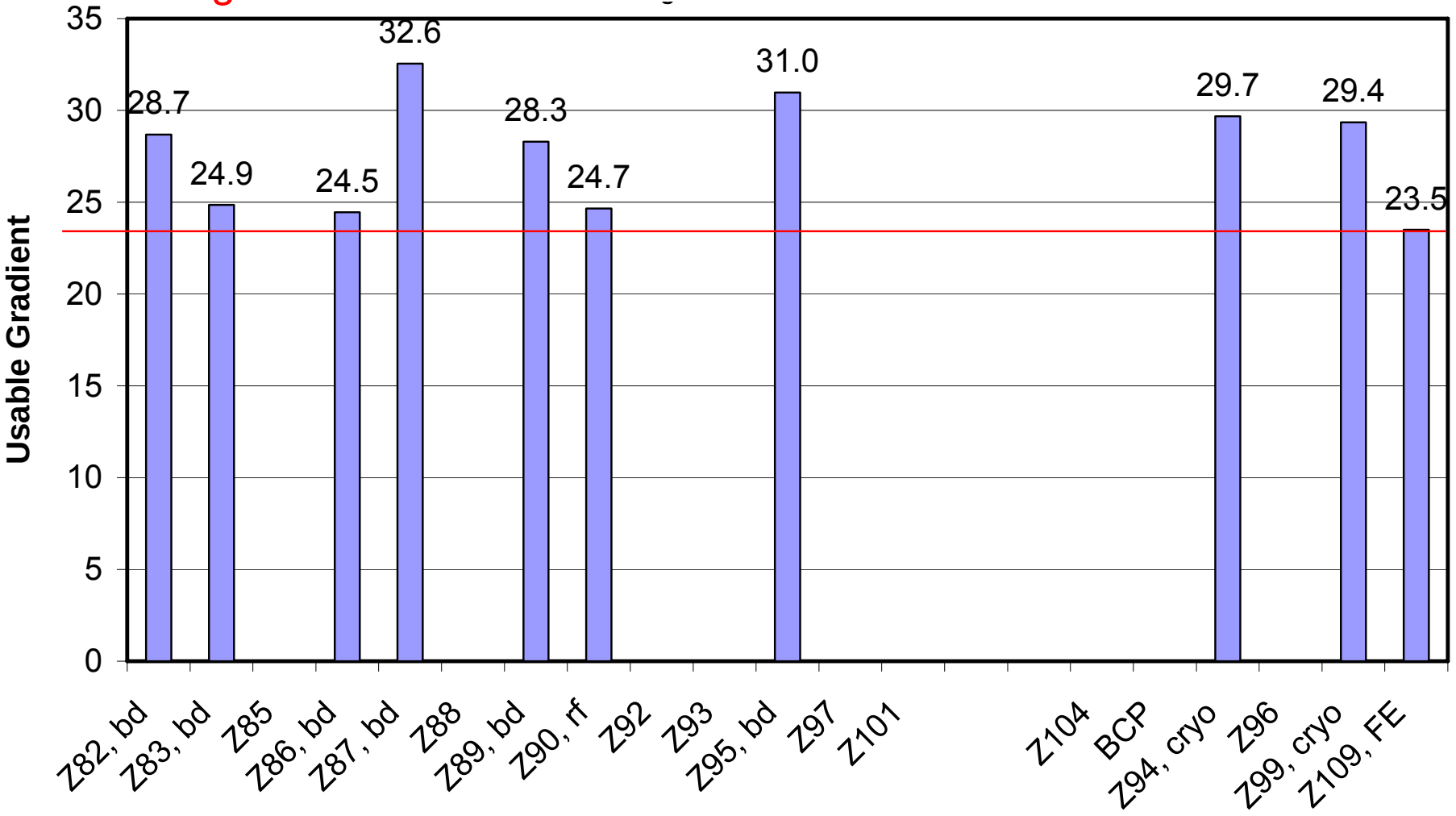
$E_{acc,max}$ after 120C bake

- Comparison of $E_{acc,max}$ after final EP and BCP-treatment after 120C bake:



Usable gradient after 120C bake

- Usable gradient after final EP and BCP-treatment after 120C bake:



Quench locations of Z-cavities

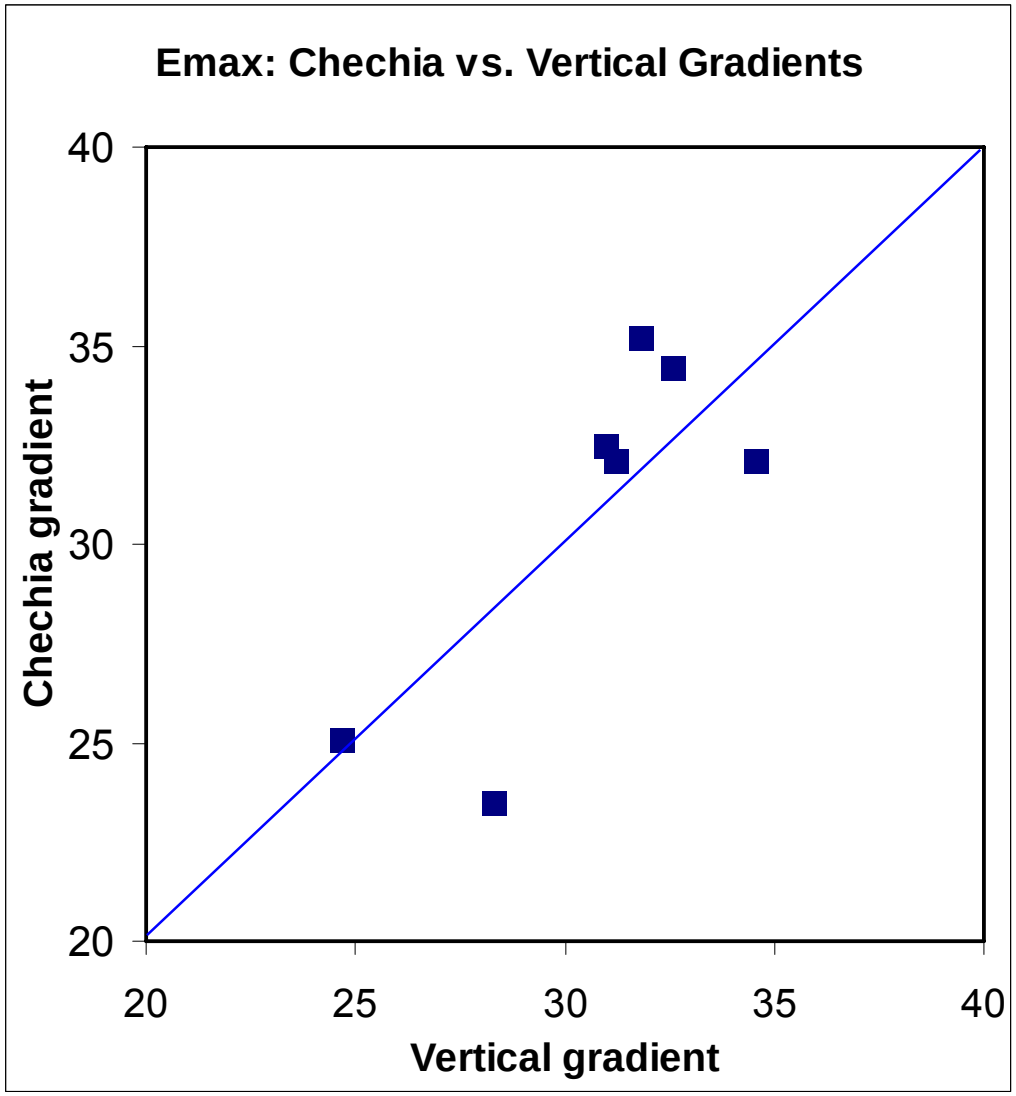
- Table of quench locations :

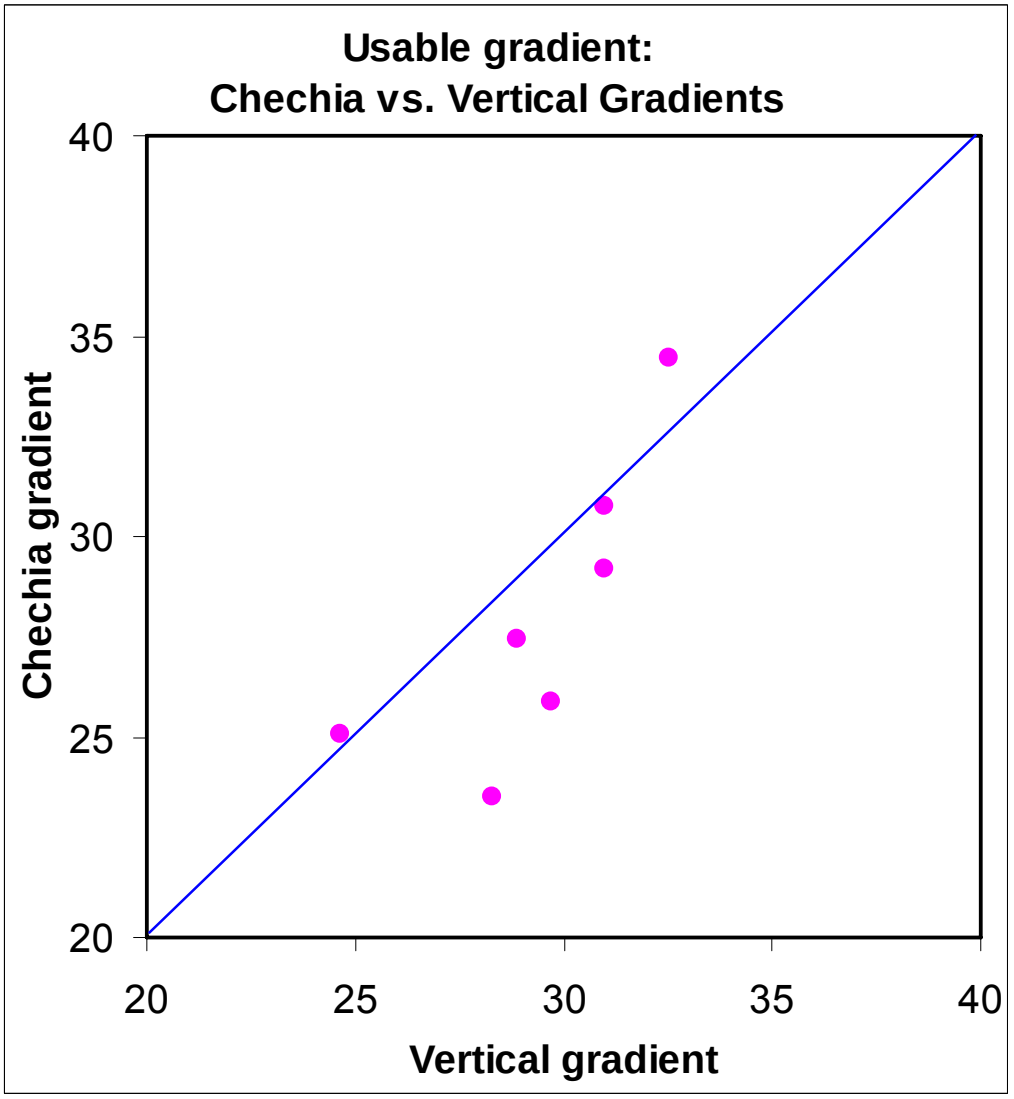
Cavity	Gradient	Quench location	Preparation + remark
Z82, test 2	28 MV/m	cell 9, equator	EP + 127C; no FE
Z83, test 2	25 MV/m	cell 1 with two hot areas i) equator; ii) upper cup	EP + 127C; no FE
Z85, test 2	33MV/m	cell 3, equator area; but highest dT 2 resistors off the equator ??	EP + 124C; some FE
Z87, test 1	29 MV/m	cell 4, lower cup; far off equator	EP; no FE
Z89, test 2	28 MV/m	7/9pi-mode(!): cell 5, lower cup, hot area from equator to iris ??	EP + 120C; some FE
Z94, test 2	28 MV/m	cell 3, upper cup, 3 resistors off the equator	BCP; few FE

Chechia-Results

- Up to now 7 cavities Chechia-tested (incl. Z83 after 1350C-heat treatment)
- All cavities EP-processed with 2 EP-processed cavities not baked before Chechia => bad Qo
- Maximum gradient $E_{acc,max}$
  => all cavities limited by quench between 23,5 MV/m to 35 MV/m
- Usable gradient:
  - 3 cavities quench limited => $E_{acc,max} \approx$ usable gradient
  - 4 cavities exceed tolerable cryo losses (partially close to quench)

Vertical vs. Chechia-Results





Summary

- Broad scatter of both, $E_{acc,max}$ and usable gradient in vertical and Chechia tests !!!
- 7 of 16 tested cavities are quench limited below 25 MV/m after EP-proc. !!
  => 3 cavities (Z83 (pre-series with fabrication problems), Z86 + Z93) with "real" quench
  => 4 cavities have field emission => FE induced quench??
  => none (except of Z83) of these cavities had T-mapping investigation !!!
- 120C-bake often gives no improvement in E_{acc} due to quench limitation !!
  (but nevertheless some improvement in Qo (cryo losses!!))
- Many cavities show significant field emission => preparation process not reproducable !!

Conclusion

- Remaining cavities need full test program
  - with 120C bake for cavities with Q-slope (> 25 MV/m)
  - T-Mapping for $E_{acc,max}$ < 25MV/m (both EP- and BCP- final treatment)

- Data situation quite poor for XFEL cavity fabrication and preparation

- Final question:
  Is this performance of both, cavity fabrication and preparation process acceptable???
  (Remark: No cavity achieves the required ILC performance.)

Addendum:

- Additional transparencies for explanation!

T-Mapping

- Z 82 test 2 (after 800C, EP + 120C bake) => cell 9 equator
- Z83 test 2 (after 800C, EP + 120C) => cell 1 with 2 hot areas i) equator; ii) upper cup
- Z85 test 2 (after 800C, EP + 124C) => cell 3 equator area, but hottest dT 2 resistors off the equator??!!
- Z87 test 1 (after 800C, EP) => cell 4, lower cup, far off equator
- Z89 test 2 (after 800C, EP + 120C) => pi-mode gives no reasonable result; 7/9pi-mode shows quench in cell 5, lower cup, hot area from equator to iris
- Z94 test 2 (after 800C, BCP) => cell 3, upper cup, 3 resistors off the equator

Why not first test for analysis before bake?

- EP-cavities with first test (11 of 16):
  Z82, Z83, Z86, Z87, Z88, Z89, Z90, Z97, Z102, Z103, Z104
- BCP-cavities with first test (3 of 4):
  Z96, Z99, Z109

- Why not first test?
  - Z85, test 4: test 1 before bake with strong FE
    test 2 after bake still strong FE
    test 3 with new EP, but rf problems
  - Z92, test 3: test 1 + 2 with 26MV/m without FE, but rf problems
  - Z93, test 2: test 1 with strong FE => alcohol rinse + HPR
  - Z94, test 2: only T-mapping added after test 1
  - Z95, test 2: test 1 with strong FE => HPR
  - Z101, test 2: only T-mapping added after test 1